

1 CLAIMS:

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3 Having thus described our invention, what we claim as  
4 new and desire to secure by Letters Patent is as  
5 follows:

6  
7 1. A method for forming a tantalum nitride layer on a  
8 substrate, the method comprising:

9 depositing the layer on the substrate by plasma  
10 enhanced atomic layer deposition of a tantalum halide  
11 precursor in the presence of a hydrogen plasma and a  
12 nitrogen plasma.

13  
14 2. The method as recited in claim 1, further  
15 comprising varying concentration of nitrogen plasma to  
16 thereby vary the amount of nitrogen in the layer.

17  
18 3. The method as recited in claim 2, wherein the  
19 concentration of nitrogen plasma is varied so that the  
20 layer has a nitrogen to tantalum concentration ratio of  
21 between 0 and 1.7.

22  
23 4. The method as recited in claim 1, further  
24 comprising reducing concentration of nitrogen plasma to  
25 zero so that a substantially nitrogen free layer of  
26 tantalum is formed.

27  
28 5. The method as recited in claim 4, wherein the  
29 concentration of nitrogen is other than zero for a  
30 first period of time, and the concentration of nitrogen

1 plasma is essentially zero for a second period of time,  
2 so that a first layer of tantalum nitride is formed and  
3 a second layer of substantially nitrogen free tantalum  
4 is formed.

5  
6 6. The method as recited in claim 5, wherein the  
7 combination of the first layer and the second layer is  
8 used as a diffusion barrier for copper.

9  
10 7. The method as recited in claim 5, wherein said  
11 second layer is deposited upon said first layer.

12  
13 8. The method as recited in claim 1, wherein  
14 temperature of the substrate is between 100 °C and  
15 450 °C.

16  
17 9. The method as recited in claim 1, wherein  
18 temperature of the substrate is 300 °C.

19  
20 10. The method as recited in claim 1, wherein the  
21 layer is used as a diffusion barrier for copper.

22  
23 11. The method as recited in claim 1, wherein the  
24 layer is deposited on a substrate selected from the  
25 group consisting of silicon, silicon having a layer of  
26 silicon dioxide on the silicon, a low dielectric  
27 constant substrate, and a porous low dielectric  
28 constant substrate.

29

1 12. A method as recited in claim 11, wherein the  
2 substrate is a low dielectric constant substrate and  
3 has a dielectric constant in the range of 2.0-3.0.  
4  
5 13. A method as recited in claim 11, wherein the  
6 substrate has copper conductors, and the layer serves  
7 as a diffusion barrier for said copper.  
8  
9 14. A method as recited in claim 1, wherein the  
10 tantalum halide is tantalum pentachloride.  
11  
12 15. A method as recited in claim 1, wherein the  
13 depositing comprises:  
14 a. exposing the substrate to the tantalum halide  
15 carried by an inert gas;  
16 b. exposing the substrate to the hydrogen and  
17 nitrogen plasma; and  
18 c repeating a. and b. until a desired thickness of  
19 the layer is obtained.  
20  
21 16. A method as recited in claim 15, wherein the  
22 exposing the of the substrate to the tantalum halide  
23 carried by the inert gas is performed at a pressure of  
24  $3.0 \times 10^{-2}$  Torr.  
25  
26 17. A method as recited in claim 15, wherein during  
27 the exposing of the substrate to the hydrogen and  
28 nitrogen plasma, partial pressure of hydrogen is  $2.5 \times$   
29  $10^{-2}$  Torr.  
30

1 18. A method as recited in claim 15, wherein a. and b.  
2 are repeated approximately 40 - 800 times.

3  
4 19. A method as recited in claim 15, wherein the  
5 exposing of the substrate to the tantalum halide  
6 carried by the inert gas is carried out for  
7 approximately 2 seconds; and the exposing of the  
8 substrate to the hydrogen and nitrogen plasmas is  
9 carried out for approximately 5 seconds.

10  
11 20. The method as recited in claim 1, wherein the  
12 substrate is simultaneously exposed to the nitrogen  
13 plasma and the hydrogen plasma.

14  
15 21. The method as recited in claim 1, wherein the  
16 substrate is sequentially exposed to the nitrogen  
17 plasma and the hydrogen plasma.

18  
19 22. An article of manufacture comprising:  
20 a substrate;  
21 a bilayer of tantalum nitride and tantalum on said  
22 substrate, each of said tantalum nitride and said  
23 tantalum being substantially free of carbon.

24  
25 23. An article of manufacture as recited in claim 22,  
26 wherein the tantalum layer comprises amorphous  
27 tantalum.

1 24. An article of manufacture as recited in claim 22,  
2 wherein said tantalum is disposed on said tantalum  
3 nitride.

4  
5 25. An article of manufacture as recited in claim 22,  
6 wherein the carbon content is below five percent.

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